Scale Models

- Build a ½" to the foot model of your course project. Maximum model dimensions are 20’ x 30’ with a maximum height of 20’.
- You may for example choose one specific element of the design for which your group would like to test various options. This could be exterior variants such as louvers or window sizes and locations, or interior variants such as light shelves, material properties or ceiling profiles.
- It is advisable to develop your design in sketch form before constructing the model.
- Please submit a few photos of your model(s).
- To build your models, you will need the following list of items:
  - Xacto or matte knife and blades
  - Straight edge for cutting
  - Architect’s scale
  - Triangle(s)
  - Tracing Paper
  - Pens or pencils for sketching
  - FoamCor (enough)
  - Glue and/or pins to hold model together
  - Tape (black if available) to prevent light leaks
  - Any other favorite model building tools and materials.

Which group has never built a model?
Daylight Availability Metrics

Historical Background: “Right of Light”

UK Prescription Act (1832): If one has benefited from daylight access across some else’s property for over 20 years, an absolute and indefeasible ‘rights to light’ is granted to the building.

“Before WWII, legal rights of light constituted practically the only profitable field for daylight experts.”
Daylight Factor Analysis - Example

Daylight Factor – Design Implications

- reference
- window head height
- glazing type
- narrow floor plan

DF > 2%
DF mean = 4.6%
Daylight Factor – Design Implications

Note, there are LEED certified buildings that are fully glazed!

Daylight Factor Use in Design

Argument:
- overcast sky as a worst case scenario
- venetian blinds (even if closed) still admit sufficient DL
Combine Daylight Factor Analysis with Shading Studies

Resulting building design good from an energy standpoint. Could it be better?
Climate-based Metrics

Limitations of DF & Avoidance of Direct Solar Gains:

- local climate data (Vancouver vs. Regina)
- building use (occupancy patterns, lighting requirements)
- movable shading devices (venetian blinds)
Solution? – Climate-based Metrics

- As opposed to a static simulation that only considers one sky condition at a time, dynamic daylight simulations generate annual time series of interior illuminances and/or luminances.

Daylight Coefficients

1. Division of the Celestial Hemisphere
2. Calculate Daylight Coefficients
Dynamic Daylight Performance Metrics

- DDS result in thousands of data points for each sensor.
- The task at hand is to reduce the data without diminishing its value for building design.
- Points for discussion:
  - time base
  - lighting requirements
  - movable shading devices

Time Base

- Daylit Hours of the year:
  + building form directly related to building site
- Occupied hours of the year:
  + daylight needs “witnesses”
  + sensitive to building use
  + self scaling: spans the whole range from 0% to 100%
  + occupancy profiles for different building zones available
Lighting Requirements - Office Work

- **Daylight Autonomy (DA):** percentage of working hours when a minimum work plane illuminance is maintained by daylight alone.

- **Useful Daylight Illuminances (UDI):** divides working hours into three bins:
  - % < 100lux (insufficient daylight)
  - % between 100 lux and 2000 lux (useful daylight)
  - % > 2000 lux (too much DL => visual/thermal discomfort)

- **Continuous DA & DA_{max}:**
  - continuous DA >40% 1 credit
  - continuous DA >60% 2 credits
  - continuous DA >80% 3 credits
  
  for 60% of work plane and DA_{max} < 1%


Climate-based Metrics - Spatial Maps

Too much daylight near the facade?
**Climate-based Metrics - Temporal Maps**

- **Daylight Autonomy**
  - DA_{500 lx} > 60%

**Annual Horizontal Illuminance**

Too much daylight near the façade!

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**Lighting Requirements - Museums**

- **Annual Light Exposure**: established upper threshold for artwork - already established used for museums (CIE TC3-22 ‘Museum lighting and protection against radiation damage’)
**Museum Lighting Requirements**

CIE TC3-22 ‘Museum lighting and protection against radiation damage’

<table>
<thead>
<tr>
<th>category</th>
<th>material classification</th>
<th>example of materials</th>
<th>lighting illuminance</th>
<th>limiting annual exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>insensitive</td>
<td>metal, stone, glass, ceramic</td>
<td>no limit</td>
<td>no limit</td>
</tr>
<tr>
<td>II</td>
<td>low sensitivity</td>
<td>canvases, frescos, wood, leather</td>
<td>200 lux</td>
<td>600 000 lux h/yr</td>
</tr>
<tr>
<td>III</td>
<td>medium sensitivity</td>
<td>watercolor, pastel, various paper</td>
<td>50 lux</td>
<td>150 000 lux h/yr</td>
</tr>
<tr>
<td>IV</td>
<td>high sensitivity</td>
<td>silk, newspaper, sensitive pigments</td>
<td>50 lux</td>
<td>15 000 lux h/yr</td>
</tr>
</tbody>
</table>

**Example: Seattle Art Museum - Arup Lighting using Daysim**

3D model of site and building

Courtesy of Arup Lighting (Matthew Franks). Used with permission.

source: [http://www.radiance-online.org/community/workshops/2005-montreal/PDF/Franks_ArupCaseStudies.pdf](http://www.radiance-online.org/community/workshops/2005-montreal/PDF/Franks_ArupCaseStudies.pdf)
Seattle Art Museum - Arup Lighting

Museum Open Hours  1,500,000+ lux-hours

Interior Illuminance Plot - Hourly Measurements

Courtesy of Arup Lighting (Matthew Franks). Used with permission.
Seattle Art Museum - Arup Lighting

Automatic Shading + Switching  555,000 lh


Courtesy of Arup Lighting (Matthew Franks). Used with permission.

Wrigley Global Innovation Center
Chicago, Illinois - AEC

- Winter Garden Atrium break area
- Views from adjacent offices


Courtesy of Zack Rogers, PE, President, Daylighting Innovations, LLC. Used with permission.
Bldg G Conversion  Hartford, CT, USA

architecture: Pratt & Whitney

general office space 130' x 310'
simulation: Kalwall

MπA Demo: Daylight Autonomy
Daylighting Metrics in Gymnasia

MS Thesis Project - Cynthia Kwan

IESNA RP-6-01 Sports and Recreational Area Lighting

- Target Illuminance
  - 500 lux for Class III (Some provisions for spectators)
  - 300 lux for Class IV (No provision for spectators)

- Uniformity ratio (max/min illuminance)
  - ≤3.0 for Class III (Some provisions for spectators)
  - ≤4.0 for Class IV (No provision for spectators)

- Glare avoidance
Case Studies

Greensburg, PA
- Area: 784 m²
- Class: IV

Colbert, WA
- Area: 534 m²
- Class: IV

Brownsville, VA
- Area: 699 m²
- Class: IV

Clouston, WV
- Area: 1397 m²
- Class: III

Largo, FL
- Area: 603 m²
- Class: IV

Alameda, CA
- Area: 1741 m²
- Class: III

Gloucester, United Kingdom
- Area: 589 m²
- Class: IV

Omaha, NE
- Area: 2694 m²
- Class: III

Walton, NY
- Area: 850 m²
- Class: III

Berea, OH
- Area: 502 m²
- Class: IV

Maldegem, Belgium
- Area: 2440 m²
- Class: III

Scottsdale, PA
- Area: 863 m²
- Class: III

Results DA & Uniformity Ratios
High-scoring Designs

Example Application: New Sports Facility

DA = 49 - 72%
Mean DA = 62%
UR = 85 % of time
4.430 Daylighting
Spring 2012

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